Physics 371 FINAL EXAMINATION December 9, 2005.

Time: 3 hours C. Rangacharyulu

The PHYSICS 371 Class MANUAL is allowed. You may use UNPROGRAMMED calculators. No other material is permitted.

Some data: Boltzmann constant= 8.617×10^{-5} eV/K
hc = 1240 eV-nm
Stefan-Boltzmann constant = 56.7 nW m^{-2} K^{-4}

Answer ANY SIX questions. If you attempt more than six questions, the best 6 will be used for your final marks.

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1. What is the inversion temperature?

   Derive the expression for the inversion temperature of a Van der Waal's gas.
   Show that it is approximately proportional to the ratio *a/b* where *a* and *b* are Van der Waal coefficients of the gas species.

2. Assume that the matter in sun is uniformly distributed in a sphere of radius R and it consists of 10^{57} hydrogen atoms. The kinetic energy of atoms in the sun is half of the magnitude of potential energies (virial theorem). Calculate the average temperature of the sun.

   Physical constants: Solar Mass= 2×10^{33} g, Solar radius R= 7×10^{10} cm,
   G= 6.6×10^{-8} dyne- cm^2/g^2

3. Start from the Wien's distribution for Blackbody radiation (same as Planck's distribution without the -1 in the denominator.

a) Use frequency (ν) as the variable to deduce the Wien's constant

b) Use wavelength (λ) as the variable to deduce the Wien's constant

Any discrepancy? If yes, what are the sources of discrepancy?

4. The stellar matter may be considered to comprise of hadrons (ground state), mesons (100 MeV excitation) and quarks (1000 MeV excitation).

a) First consider a stellar matter made up of only hardons and mesons . At what temperature will the meson population be one-half of hadron population?

b) Now consider the matter made up of three types of excitations at the temperature deduced in section a). What are the relative populations of hadrons, mesons and quarks?

c) What is the average energy for case b).

5. What are intensive and extensive variables? Give one example for each of them. What is Gibb's paradox? How is it resolved? You should show your calculations.

6. We argued, based on the fact that probability an s^{th} state is populated $|p_s| \leq 1$, that the chemical potential of Bosons is a negative quantity.

   Make those arguments to prove the point.

   Extend this probability argument to Fermions and derive the limits on the chemical potential as function of temp.

   Hint: You may truncate the exponential terms to the first power in β.

7. The condensation temperature of ^4He is $T_c = 2$ degrees.

   Calculate the space available for ^4He atom at this temperature.

   Calculate the de Broglie wavelength at this temperature and compare the two.

   Comment on the relative magnitudes to draw conclusions on the phenomenon of condensation.

   data: mass of He = 3700 MeV/c^2.

8. A continuous real variable has a probability $p(x)dx$ of occuring in the interval x and x+dx, where

   $$p(x) = C\, x^{-\alpha}$$

where 'C' is a normalization constant and 'α' is real, positive number. Clearly, there is a minimum value $x = x_{min}$ below which this distribution does not hold.

Calculate 1. The normalization constant in terms of α and x_{min}.

2. Show that the first moment

$$\langle x \rangle = \frac{\alpha - 1}{\alpha - 2} x_{min}$$

3. In general, $\langle x^m \rangle = \dfrac{\alpha - 1}{\alpha - 1 - m} x^m{}_{min}$ for $m < \alpha - 1$.

*****END OF EXAMINATION*****